

FURTHER DISCOVERIES OF GLACIATION, WEST COAST, TASMANIA.

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Through the courtesy of Messrs. E. J. Dunn, R. M. Johnston, and A. Morton I have received the two former gentlemen's and Mr. Montgomery's papers of last year on Glaciation.

First I shall make a few comments on these papers, then relate my own experiences since writing on this interesting and important subject.

Both Messrs. Johnston and Montgomery take exception to my giving Mr. Dunn the honour of being the discoverer of land glaciation in Tasmania. I was quite aware that *evidences* of boulders, etc., transported by floating ice had been discovered, and surmises made that land glaciation had existed, but I still think that Mr. Dunn was (to use Mr. Montgomery's own words) "the first to bring forward *indisputable proofs*" of prehistoric glaciers, and this was my meaning when I wrote last year.

With regard to former discoveries enumerated in Mr. Johnston's list of "Principal Sources of Reference," I might rank as one of the early discoverers of *evidences*, although not mentioned in this list. For in 1883 I visited Lake Dixon, and also passed over Painters Plains, and was struck by the number of scattered granite and greenstone boulders and large boulders of the latter rock resting on the summit of Artist Hill and other prominent heights; also similar evidences all through the Collingwood Valley. Here the boulders were grooved, and the positions in which they were lying, "end on," pointed that they had been transported by the agency of glaciers from the Eldon Peak and Mount Gell. In my Government report, 1883 (and I believe 1886), which was printed and laid on the table of the House of Assembly, the above statement is recorded. In conversations I had about this time with my old friend Sprent and Mr. Johnston, I was under the impression that both concluded that the large boulders had been deposited by floating ice, and as late as 1889 Mr. Stephens, Director of Education, expressed this theory when asked by the Bishop of Tasmania, at Mount Arrowsmith, his opinion relative to the Collingwood boulders. Mr. Johnston's first paper with reference to erratics on Maria Island, brought by floating ice, was in 1884.

In 1887 another paper by his fluent pen is recorded, which I conclude would be written after his trip in 1887 with Mr. C. P. Sprent and party along my track of 1883 and 1886, which at the time of their journey had for a great part of its distance been formed into a horse track.

It is on this journey, following on my footsteps four years later, that Mr. Johnston first finds his evidences of land glaciation at Lake Dixon, in the vicinity of Mount Gell. Being the first explorer in this direction to the West Coast, in all probability Mr. Sprent had one of my reports with him with remarks as to glacial action, as it was principally through his instructions as Deputy Surveyor-General I conducted my explorations. It was also after this trip that Mr. Sprent wrote his paper for the Victorian Branch of the Royal Geographical Society of Australasia, containing notes relative to glaciation in Tasmania. During this tour Mr. Johnston mentions that he spent three days in examining more particularly the rock formations on Mounts Owen, Lyell, and Sedgwick. This statement requires explanation, as it would appear that glacial action at that date had been found in the vicinity of Mount Sedgwick; to have reached Mount Sedgwick alone at that time four long days would be required to complete the journey there and back, therefore we must conclude our good friend had the use of a flying machine, or was mistaken in the mountains he visited.

With regard to the ancient glacial conglomerate, Mr. Johnston agrees with Mr. Dunn and myself that the conglomerates at Mounts Read and Sedgwick have originally been deposited under water by floating ice and belong to a very ancient epoch.

Mr. Dunn in his paper entitled "Glaciation of the Western Highlands, Tasmania" (in Proc. R.S. Vic., 1893), states with reference to the Mount Read conglomerate:—"There is a marked similarity in the nature of the cementing material and in the character of the embedded pebbles and boulders to the glacial conglomerate found at Wild Duck Creek, Victoria, and to the Dwyka conglomerate of South Africa, and they probably all belong to a very ancient epoch, either near the close of the Palæozoic period or else the commencement of the Secondary era." Mr. Johnston (page 35) says: "It is possible that some of the thick conglomerate beds occurring in the vicinity of Mount Tyndall, Mount Lyell, and Mount Owen* in which marks of ice action are reported to have been recently discovered by Messrs. Dunn and Moore may yet prove to belong to the same horizon" (Permocarboniferous). The ice marks in the conglomerate beds at Mounts Read and Sedgwick may belong to the Permo-

* Specimens with ice marks were sent from these conglomerates last year to illustrate my paper.

carboniferous period as Mr. Johnston surmises, but the boulders and pebbles in the recent moraines north of Lake Margaret and on the Linda Company's ground at Mount Lyell cannot be confounded with the ancient conglomerates, for the scored boulders are all of local origin, differing in character and form from the rocks of the ancient conglomerate; the scorings are also much deeper and decided in appearance. If parts of the older conglomerate had been disintegrated from the parent mass and become mixed with the recent morainal matter, the scorings would have been obliterated, for the best specimens from the ancient beds, bearing the deepest ice marks, are in rocks of a soft nature, though some of the harder ones are marked with very fine scratches.

Mr. Montgomery in his able paper read last year, entitled "Glacial Action in Tasmania," remarks that I state Mounts Sedgwick and Dundas are capped with greenstone; he adds to these Barn Bluff, Mount Pelion, Mount Ossa, the Ducane Range, the Eldon Range, East Mount Pelion, and the Oakley Range as showing the same feature. The additions compose part of the great greenstone plateau of the centre of the island, or I should say a long offshoot of the same, dividing the waters of the northern and western rivers. This high dividing chain of mountains should not be confounded with the West Coast Range with its two isolated peaks of greenstone, Mounts Dundas and Sedgwick; except these and the schistose summits of Mounts Read and Darwin, all other eminences in the West Coast Range are capped with a quartzose conglomerate. In my paper I noted the peculiarity of these greenstone peaks as differing from the formations on the other heights of the range.

Mr. Montgomery found in his additions the columnar greenstone resting on the coal measures, which is a noticeable feature on the great greenstone plateau further south from his explorations, and surmises what he terms the moraine at Mount Sedgwick to be coal measures similarly situated. As we once visited Mount Dundas together, Mr. Montgomery is aware that this feature is not seen there, and when he has leisure to examine Mount Sedgwick, I do not think he will conclude that the greenstone rests on the *ancient glacial conglomerate*, but he will find rounded detached masses of the conglomerate resting on a porphyretic spur on the western side of the mountain, which have been disintegrated from the parent bed situated on the south-east side, and probably carried to their present resting places during the recent glacial epoch. He adds, "I cannot think it at all probable that Mr. Moore is correct in referring the conglomerate containing fossils to the action of floating ice. It seems more likely that it is a moraine drift derived from the lower beds of the

carboniferous formation, which farther north, near Barn Bluff and Cradle Mountain, consists mainly of conglomerate. These would supply the stones, granite, slate, and porphyry, etc., which Mr Moore has noticed, and also the fossils, and I have little doubt when he comes to examine the country more thoroughly he will find these beds in situ under the greenstone capping. It is hardly conceivable that if the conglomerate was deposited by floating ice action in Permo-carboniferous times, which is what Mr. Moore's words seem to imply, that it should happen that the only proofs of such ice action should be found in a region where there has been evidently severe glaciation at a much later date. Before accepting such a theory, we should first have to eliminate all possibility of the conglomerate having been formed at the later period."

So able an authority as Mr. E. J. Dunn, F.G.S., who discovered a similar bed of glacial conglomerate between Moore's Pimple and Mount Read at an elevation of 3,000 feet, is convinced that it was deposited by floating ice in Permo-carboniferous times, and believes it to be identical with the conglomerates he has reported upon at Duck Creek, Victoria, and in Africa, and further on I hope to convince Mr. Montgomery that the above conclusions are correct.

Let us take Mr. Montgomery's theory "that it is a recent morainal drift derived from the lower beds of the carboniferous formation near Barn Bluff and the Cradle Mountain, which conglomerates would supply the granites, slates, porphyries, etc."

The Cradle Mountain, the highest elevation in Tasmania, is a little over 1,500 feet higher than the deposit at Mount Sedgwick, and if Mr. Montgomery had stated the height at which the lower carboniferous beds occur, it would have added more weight to his argument, and also shown if it were possible that the non-local rocks in the ancient glacial conglomerate at Mount Sedgwick could be derived from this locality, either *at an ancient* or more recent date of glacial phenomena. Besides, if this were a morainal drift derived from this distant locality, would we not expect to find some signs of the more elevated greenstone rocks in the shape of erratics and other non-local rocks on the high plateau round Mounts Geikie, Tyndall, Read, Sedgwick, and Murchison? besides the conglomerate would not be confined to two isolated spots. This would also apply to Mr. Johnston's suggestions that the glaciers may have descended from the great plateau, and that the arrow head of lineal direction of the general trend of striæ may be turned the other way. The question of the small collecting ground remaining above the ancient snow line is difficult to solve.

Is it not more probable that in the recent ice period the rivers

of ice from the Cradle Mountain and Barn Bluff have flowed down and eroded the gorges of the Mackintosh and Murchison Rivers and their tributaries, which at the present time drain these high altitudes, than travelled over their deep-cut gorges a distance of forty miles, to the high land around the peak of Mount Sedgwick? and to substantiate this Mr. Montgomery says "there are grounds to believe that the Valley of the Mackintosh has been scoured out by glacial action." I now hope Mr. Montgomery will accept this theory, and eliminate all possibility of the conglomerate having been formed at the later period, for the only proof of such ice action is *not confined* to a region where there has been evidently severe glaciation at a much later date.

In the beginning of April this year (1894), while travelling from Zeehan to my old friend Sprent's top crossing of the Pieman River, I came across an extensive bed of a similar glacial conglomerate to that at Mounts Read and Sedgwick lying in a low basin-shaped valley about four miles north from the town of Zeehan, and west of the horse track leading to the punt placed on the Pieman River for the use of the Stanley River tin miners.

The bed, as near as I can approximately estimate, is about a mile long by a quarter of a mile wide, and appears of no great depth. I picked up numerous scored pebbles, but in the limited time at my disposal did not obtain any carboniferous fossils. Yet I feel positive they are to be found, for the rocks composing the conglomerate and the binding material are identical with those of the former discoveries of Mr. Dunn and myself.

The height of this bed is between three and four hundred feet above sea level, and if not formed by the agency of floating ice in the Permo-carboniferous age, Mr. Montgomery must allow that the recent glaciers have descended to a much lower level than he anticipated. Finding this extensive deposit at such a low altitude, far from any proofs of recent glacial action, and precisely similar to the other more elevated conglomerates at Mounts Read and Sedgwick, it is only reasonable to suppose that all belong to the same glacial age and method of deposit, as Mr. Johnston describes it, the ancient glacial epoch of Permo-carboniferous age.

In these notes I regret to have to dispute the theories of much abler men in the scientific world than myself, but what information I have gathered is from actual observation, and my records only embrace indisputable proofs of glacial action, which I trust will throw more light on the true aspect of this interesting subject.

In the beginning of July last year (1893) I had occasion to visit the western base of the Craycroft Hills, east of Macquarie Harbour; here I found a huge terminal moraine,

containing boulders principally Devonian conglomerate, in size from the smallest atom to many tons in weight. The morainal matter is composed of rocks of a local origin, and all scored specimens picked up were undoubtedly so, the ice marks being as plainly visible as in the rocks of other recent moraine stuff in localities before enumerated. A small, turbulent, deeply-cut, precipitous stream runs parallel to the moraine, its bed being choked by huge rounded Devonian conglomerate boulders, forming miniature falls and blocks in the creek. The height of this interesting discovery above sea level is only 250ft, and without doubt the deposit has been brought by glaciers from the Craycroft Hills (named after a niece of Sir John Franklin) or Frenchman's Cap. The aspect of these hills, viewed in the distance, plainly shows that a great glacial erosion has scoured their slopes, although their present height cannot be more than 3,000ft. above sea level.

Mr. Montgomery in his paper remarks:—"I think we must come to the conclusion that the whole of the deep gorges among these western mountains now occupied by the head waters of the Pieman, Henty, and King Rivers have been at no very distant period of time occupied by rivers of ice;" and further on says, "If we allow this we must admit the ice came down to within 500 or 600 feet of the present sea level."

These conjectures are correct, for the moraines I reported finding in the King Valley in my supplementary notes last year are about 500 or 600 feet above sea level; and now we have a recent moraine in which indisputable proofs of glacial action exists at a very much lower altitude.

My last discovery is the most important and interesting of all, and will probably throw more light on the extent and age of our glacial action.

In the first week in June, 1894, the long promontory west of Farm Cove, Macquarie Harbour, forming the western boundary of that inlet was visited. Here I found a deposit of morainal matters containing boulders a quarter of a ton in weight. These masses covered the point, beach, and ran far out into the water. Where exposed to the present wave and tidal action all the finer markings and scorings were obliterated, but above and at high water level the ice marks are beautifully illustrated. (Illustrative specimens broken from the boulders, and boulders found at a later date are forwarded.) On my return, two months later, owing to high gales, I had to remain at this point, and spent a day and a half examining the locality. All round the promontory, and for a considerable distance on the Farm Cove side, the striations are really wonderful and many boulders are tons in weight; the largest measured was 15ft. long by 6ft. wide

and deep respectively. Travelling five miles in a north-west direction past Phillip Island, along the present beaches the grooved and scored masses are scattered over the whole of that distance, and similar boulders, with the ice marks obliterated, are found extending far out into the waters of the harbour. Where the raised tertiary beaches have been denuded and now form the present sandy beaches the boulders on the land are covered from sight, but in the shallows of the shore they are plainly visible. The boulders rest on the lignite beds which have been denuded of their original overburden, but cannot be traced below the consolidated sand and fine clayey sedimentary cliffs. They are either exposed to all atmospheric influences or embedded in a recent earthy matter. On the eastern side of the point, the entrance to Farm Cove, a third of the way across is blocked even for navigation by small crafts by masses of boulders, rising in places above high water mark, and forming resting haunts for sea birds.

Let us follow the shores of the harbour past my recent explorations towards the coast to Sophia Point, or even to Strahan. Here we find boulders forming long points, in many places strewn over the present beaches or extending into the water, which if examined probably will prove to be ice-borne blocks.

Raised tertiary beaches enclose nearly all the north-eastern shore of the harbour, as it were, with a formidable wall of consolidated sand and mud. Nowhere do we find boulders in the consolidated mass, only on the unconfined points, heaped together on the narrow roadway at the base of the precipitous sandy cliffs jutting out into the water, or opposite the localities where the raised beaches have been cut out or almost wholly swept away, as at Kelly's Basin and at Farm Cove. On the summits of these sandy walls and all over the surrounding country what I now conclude is morainal matter extends to Mounts Sorell and Darwin; for the large boulders we find could not have been so shaped, rounded, or deposited by any other means but ice. Travelling up to the valley between Mounts Sorell and Darwin the bed rocks of the creeks are worn smooth, and very little sedimentary material left in their courses. The valley is open, and ranges from 1,000ft. to 1,300ft. above sea level, is a mile broad and two and a half miles long, and has been swept clean of most of the morainal matter, leaving here and there huge, rounded, polished, and grooved boulders, in some instances as large as those described by Mr. Dunn as the Pilgrim, Traveller's, etc., in the Tyndall country. One monster measured 36ft. long, 24ft. broad, and 10ft. high.

The enclosing slopes and shoulders of Mounts Sorell and Darwin are all well rounded and in many places grooved, the

grooves running parallel with the valley, indicating that a great stream of ice has flowed down the course of the Clarke River, located in the centre of the valley, smoothing the bed rock and carrying the debris brought from the surrounding heights into the lowlands. The smaller tributaries are like the larger streams cut down into the solid rock, and contain few traces of morainal matter in their beds. The soft schist and porphyritic rocks on the hummocky and flat rises at the head of the valley have their exposed surfaces worn smooth, and are overlaid with a thin coating of fragmentary ice-worn quartz, or have large erratics with perched blocks resting on their ice-worn summits. The river, after leaving the valley, takes a south-westerly course, and cuts through two large spurs, and in its now rapid course runs straight for Farm Cove, which beautiful inlet and its glaciated boulder promontory make a charming picture looking from the south end of the valley, the only portion of the harbour visible. After reaching the lower lands the stream turns to the eastward and runs in a sluggish course, emptying at last into Kelly's Basin. Rocks similar to those observed on the harbour can be obtained on the highlands, and it is reasonable to suppose they have been transported from there down the Clarke River gorge, seeing that the general trend of that stream is in the direction of the glacial point.

If we look at the precipitous south end of Mount Sorell, not more than three miles from Farm Cove, with its steep spurs running into the harbour, it is easy to suppose that if the glaciers have not descended to water level, that blocks of ice and ice-worn boulders may have been hurled into the harbour. From what I have observed I favour the opinion that the glaciers have travelled to water level, for we find spurs close to the shore of Kelly's Basin and Farm Cove stretching for two to three miles in the direction of Frenchman's Cap, Craycroft Hills, Mounts Sorell and Darwin, covered with morainal matter. These spurs or moraines are composed of a clay intermixed with pebbles and boulders, wholly different in composition and material to the sedimentary raised beaches.

I feel no doubt in my own mind that the pebbles and boulders are ice-borne, for we find in many cases two sides and an end planed, while other parts are rough, a noticeable feature in glaciated stones, compared with the rounded surfaces of those worn by water, indistinct scorings can be observed by a practised eye, to the sceptical perhaps they would not be distinguishable.

Mount Sorell is one of the highest prominences in the West Coast Range, and though we do not find the striæ and grooving on the rocks at such a high altitude as in the vicinity of Mount Tyndall, this would give a larger collecting

ground above the ancient snow line, and seeing that the valleys have been worn and eroded to a greater extent at much lower levels, is it not more than probable that this higher eminence, the seat of prehistoric glaciers, standing, as it does, near the coast line, has let loose its glaciers, which have descended down the steep slopes with nothing to impede their course, and have tumbled into the waters of the harbour before melting?

A connecting ridge, with grooved summit 1,700 feet high between the two mountains, divides the watershed of the Clarke and Garfield Rivers. The latter stream drains the north ends of the mountains, and is a tributary of the King River. The northern valley is at a much lower altitude (800 feet) and narrow, the gorges are more numerous, longer, and deeper cut. The rocks are all worn smooth, and in places grooved. An occasional erratic is seen, but little morainal matter left in the beds of the creeks, showing that the ice has travelled a considerable distance in this direction.

The principal gorges north and south of the ridge head from Mount Darwin, and the greatest waterflow at the present time comes from that mountain, whose summit I stated in my last year's supplementary notes has no signs of striæ, the rocks being rounded.

The low lying moraine, with its glaciated stones near the Craycroft Hills, conclusively proves that the ice has descended to much lower levels than anticipated by Messrs. Johnston and Montgomery, and the scored boulders near Farm Cove indicate, if not in a general way, in some cases the glaciers have reached sea level.

It is improbable that the boulders at Farm Cove are the results of icebergs in the Permo-carboniferous period, for it will be observed that the scorings on the illustrative specimens are well marked and clear, as if only scratched a few years ago, besides the boulders lie without surface covering, and their polished and scored surfaces have been exposed to all atmospheric influences, and in many cases to wave action. Such being the case, it is hardly possible that the ice markings would have remained so intact for so long a period, *i.e.*, since the Permo-carboniferous era.

If the scored boulders had been deposited by floating ice we would expect to find similar evidences in the tertiary beaches, which I need hardly say have been elevated since the ancient ice epoch; this not being so clearly proves that our glaciers in some cases have descended to sea level. Also the non-evidence of any signs of ice action, except erosion in the palaeogene-lacustrine deposits at Macquarie Harbour will give a good proof as to the age of our recent land glaciation.

Before concluding, I might mention that in the beginning of 1893, during a tour down the coast south of the harbour,

on the quartzite hills four or five hundred feet high, about two miles from and lying above the entrance to the harbour, I noticed the rocks very worn, smooth, and planed, and at the time felt convinced that it was by the agency of ice that the natural surface of the quartzite had been altered, though the positive proof of striæ and groovings was wanting.

It may be surmised that these planed surfaces and the deposits of glaciated boulders on the shores of the harbour are the results of stranded polar drift ice. If such was the case the ice drifts must have occurred before the elevation of the land and beaches, and if so we would obtain traces of glaciation in the palæogene deposits, which we do not. It may have been possible since the elevation of the land for drift ice to have been driven into the harbour through the entrance, but surely we should see some evidences of stranded bergs there.

The similarity in the composition of the scored boulders at Farm Cove is more puzzling to account for than any other feature in the matter.

I regret, through pressure of time, being unable to add a map of this district, for the charting on the large official map of the colony of Mounts Sorell and Darwin and the surrounding country is very incorrect, both mountains being mapped three miles too far to the eastward and not far enough south, besides other physical features being incomplete and wrongly depicted. In 1887 I corrected the errors on the Mines Office chart, and that map would give a better idea of this locality.